APPENDIX A

METHOD FOR MANUFACTURING METAL MASTER OF INFORMATION RECORDING DISC AND METAL MASTER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The disclosure of Japanese Patent Application No. 2003-049348 filed February 26, 2003 including the specification, drawings, and claims is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of Invention

[0002] The present invention relates to a method for manufacturing a metal master for fabrication of information recording disc substrates and to a metal master.

2. Description of Related Art

[0003] It is crucial in fabrication of an information recording substrate such as an optical disc that the disc substrate has ~~high~~ a highly precise shape ~~precision~~ because if ~~a shape~~an error in such a disc substrate is large, it will lead to a large variation in reflectance, which will decrease the accuracy of recording/reproducing information.

[0004] A typically known method for manufacturing an information recording disc substrate involves the steps of applying a positive type ~~photoresist~~ photoresist, for ~~example~~ example, on a glass substrate, irradiating the photoresist with a laser beam, developing and removing the exposed photoresist to produce a glass master with fine depressions and protrusions, copying the fine depressions and protrusions of the glass master to a metal master and then to a stamper, and arranging the stamper in a mold for molding resin to fabricate an information recording disc substrate. The information recording disc substrate manufactured according to this method has an information recording region in which pits and/or grooves are formed by depressions and protrusions copied from the glass master in a reversed ~~fashion, namely~~fashion. Namely, the depressions are copied as protrusions and the protrusions are copied as depressions. However, it is possible to provide an information recording disc substrate having pits and/or grooves identical to the depressions and protrusions of the glass master (equally copied) if a mother is produced by copying the depressions and protrusions of the metal master ~~thereto~~ in a reverse fashion and then a stamper is produced by copying the protrusions and depressions of the mother ~~thereto.~~in a reverse fashion. It is also possible to provide an information recording disc substrate having pits and/or grooves identical to

depressions and protrusions of the glass master (equally copied) if the metal master is used as a stamper.

[0005] The term "metal master" used herein shall be defined as a matrix obtained by removing a conductive film and an electrolytic plating layer formed on a glass master. In other words, herein, any matrix obtained by removing a conductive film and an electrolytic plating layer formed on a glass master shall be called a metal master whether it is used as a stamper or as a matrix for fabricating a stamper or mother.

[0006] The terms "pits" and "grooves" are generally used in relation to CD media (Compact Discs) or DVD media (Digital Video Disk or Digital Versatile Discs) to mean fine depressions formed on an information recording disc substrate for recording information therein. In the present specification, however, the terms "pits" and "grooves" shall be used, for the sake of convenience, to mean fine projections as well as fine depressions formed on such an information recording disc substrate that has a light-transmitting layer formed thereon and receives laser beams from the side of this light-transmitting layer.

[0007] ~~In the prior art,~~Conventionally, an information recording disc substrate having ~~high~~ a highly precise shape ~~precision~~ has been produced by fabricating a high-precision glass master by smoothly polishing a glass substrate and copying the high-precision glass master to a metal master or the like.

[0008] It should be noted, however, that even a glass master with ~~high~~ a highly precise shape ~~precision~~ produced in this manner may generate a slight ~~shape~~ error in the shape of the metal master when the shape of ~~a~~ the glass master is copied to ~~a~~ the metal master. For example, if the formation of a conductive film or an electrolytic plating layer is defective, or if the conductive film and the electrolytic plating layer are peeled off from each other, the ~~shape~~ error in the shape of the metal master will be increased to an extent such that a metal master thus produced is not usable. For coping with this problem, various technologies have been developed to form a conductive film and an electrolytic plating layer such that the ~~shape~~ error ~~of a~~in the metal master can be minimized (see, for example, Japanese Patent Publication No. 2663912). As a result, the ~~shape~~ error in a metal master now rarely poses a problem in practical use.

[0009] Nevertheless, when comparing various information recording discs with equivalent shape errors, those with shallower pits and/or grooves tend to exhibit larger variation in reflectance.

[0010] In recent years, there has been ~~a tendency that~~an increase in the production of information recording discs with shallower pits and/or grooves than conventional information recording discs ~~ones are increased~~ to cope with the ~~situation such as the~~ increase ~~of~~ in the capacity of information recording discs or the diversification of recording methods. For example, ~~as for~~in DVD-R media (Digital Versatile Discs-Recordable), the depth of grooves is approximately ~~150nm,~~ 150 nm, ~~and as for~~in MD media (Mini Discs), the depth of grooves is approximately 100 nm, ~~whereas as for~~and in DVD-RW media (Digital Versatile Discs-Rewritable), the depth of grooves is ~~typically~~ approximately 30nm.

[0011] Also, there has been proposed ~~an~~ a large capacity information recording disc ~~with large capacity~~ in which an information recording disc substrate is provided with a light-transmitting layer with a thickness as small as about 0.1 mm. It is believed that, even in such a large-capacity information recording disc, the depth of grooves is desirably about 30 nm.

[0012] As the depth of pits and/or grooves of information recording discs becomes smaller, there has arisen a new ~~problem that a~~problem. The small shape error in metal masters, that ~~is~~ was not problematic in conventional technologies, ~~becomes to exert~~can cause harmful effects ~~to~~ that result in variation in reflectance of information recording discs with large capacity (i.e., smaller pits and/or grooves) and hence ~~to~~ a decrease the information recording/reproducing accuracy of the large capacity recording discs.

SUMMARY OF THE INVENTION

[0013] ~~The present~~ In view of the foregoing problems, various exemplary embodiments of this invention ~~has been made in view of the foregoing problems and has an object to~~ provide a metal master with ~~higher~~ a more precise shape ~~precision~~ than conventional ~~ones and~~metal masters. Furthermore, various exemplary embodiments of the invention provide a method for manufacturing such a metal master.

[0014] ~~The present~~Various exemplary embodiments of the invention ~~has achieved~~achieve the foregoing object by forming a conductive film of a metal master to have a thickness greater than the thickness of conventional ~~ones~~metal masters.

[0015] Although it is not clearly known why the shape precision of a metal master can be improved by forming a conductive film of the metal master to have a thickness greater than conventional ones, the reason can be largely assumed as follows.

[0016] ~~For the formation of~~In the first step of forming a conductive film, a catalyst is applied ~~in the first step~~, but it is difficult to make the thickness of the catalyst layer uniform. ~~If~~ Thus, if a conductive film ~~thus~~ is thin, it is believed that any nonuniformity in the

thickness of the catalyst layer will cause a corresponding nonuniformity in thickness of the conductive ~~film, which~~film. The thickness of the conductive film affects the electrolytic plating layer, thereby contributing to a small error in the shape ~~error~~ of ~~a~~ the metal master. To cope with this problem, a conductive film can be formed thick enough to absorb the nonuniformity in thickness of the catalyst layer, and hence the nonuniformity in thickness of the conductive layer can be minimized. ~~It is believed that~~As a result, a metal master with ~~high~~ a highly precise shape ~~precision~~ can be formed by forming ~~an~~ the electrolytic plating layer on the conductive film that has been formed with minimal nonuniformity in thickness.

[0017] Further, when a conductive film is thin enough for the depth of pits and/or grooves, it is believed that the effect exerted by such thin conductive film to the ~~shape~~ precision of the shape of the pits and grooves is small because fine projections of a metal master corresponding to the pits and/or grooves are mainly constituted by an electrolytic plating layer. However, as the depth of pits and/or grooves becomes smaller, the percentage occupied by the conductive film in the constitution of the fine projections of the metal master is increased so that the fine projections are constituted by the conductive film and electrolytic plating layer serving like a composite material, which contributes to ~~a shape~~an error in the shape of the fine projections of the metal master. To cope with this, it is believed that the ~~shape~~ error in the shape of the fine projections can be decreased by forming the conductive film thick enough ~~such~~ that the projections of the metal master are mainly constituted by the conductive film.

[0018] In other words, while it has been conventionally believed ~~conventionally~~ that an electrolytic plating layer mainly constitutes a metal master and a conductive film is only an electrode for forming the electrolytic plating layer, ~~the present~~various exemplary embodiments of the invention ~~improves~~ improve the precision of the shape ~~precision~~ of a metal master by using a conductive film ~~more positively~~ as a more substantial constituent of the metal master. Thus, ~~the present~~various exemplary embodiments of this invention ~~has been made~~are based on ~~the~~ a view point and conception ~~completely different from the~~ contrary to conventional ~~ones~~practice.

[0019] ~~The forgoing object can be achieved by the invention as described below.~~Accordingly, various exemplary embodiments of the invention provide

~~(1) A~~a method for manufacturing a metal master ~~comprising the steps of:~~including

forming a conductive film by an electroless plating method on a glass master having fine depressions and protrusions for forming an information recording region of an information recording disc;

forming an electrolytic plating layer by an electrolytic plating method on the conductive film; and

removing the conductive film and the electrolytic plating layer from the glass master to provide a metal master, wherein

the conductive film is formed to have a thickness of 35 nm to 200 nm.

~~(2) The method for manufacturing a metal master according to said (1), wherein~~

~~the conductive film is formed to have a thickness of 40 nm or more.~~

~~(3) The method for manufacturing a metal master according to said (1), wherein~~

~~the conductive film is formed to have a thickness of 45 nm or more.~~

~~(4) The method for manufacturing a metal master according to said (1), wherein~~

~~the conductive film is formed to have a thickness of 50 nm or more.~~

~~(5) The method for manufacturing a metal master according to any one of said (1), (2), (3) or (4), wherein~~

~~the conductive film is formed to have a thickness of 150 nm or less.~~

~~(6) The method for manufacturing a metal master according to any one of said (1), (2), (3) or (4), wherein~~

~~the conductive film is formed to have a thickness of 120 nm or less.~~

~~(7) The method for manufacturing a metal master according to any one of said (1), (2), (3) or (4), wherein~~

~~the conductive film is formed to have a thickness of 90 nm or less.~~

~~(8) The method for manufacturing a metal master according to any one of said (1), (2), (3) or (4), wherein~~

~~the conductive film is formed to have a thickness of 60 nm or less.~~

~~(9) The method for manufacturing a metal master according to any one of said (1), (2), (3) or (4), wherein~~

~~the conductive film is formed to have a thickness of 55 nm or less.~~

[0020] ~~(10) A~~Alternatively, various exemplary embodiments of the invention provide a method for manufacturing a metal master ~~comprising the steps of:~~including

forming a conductive film by an electroless plating method on a glass master having fine depressions and protrusions for forming an information recording region of an information recording disc;

———forming an electrolytic plating layer by an electrolytic plating method on the conductive film; and

———removing the conductive film and the electrolytic plating layer from the glass master to provide a metal master, wherein

———the conductive film is formed to have a thickness greater than a step height of the fine depressions and protrusions of the glass master.

~~———(11) A metal master manufactured with the method for manufacturing a metal master according to any one of said (1), (2), (3), (4), (5), (6), (7), (8), (9) or (10).~~

[0021] ~~(12) A~~Various exemplary embodiments of the invention provide a metal master ~~comprising~~ including a conductive film having copied fine depressions and protrusions for forming an information recording region of an information recording disc, and an electrolytic plating layer formed on the conductive film, wherein

———the thickness of the conductive film is greater than a step height of the fine depressions and protrusions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Various exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings, wherein:

[0023] Fig. 1 is a cross-sectional view schematically showing the configuration of a metal master according an embodiment of the present invention;

[0024] Fig. 2 is a flow chart showing the outline of a method for manufacturing the metal master;

[0025] Fig. 3 is a flow chart showing the details of the steps for forming a conductive film of the metal master;

[0026] Fig. 4 is a cross-sectional view schematically showing the steps of forming a glass master used for the manufacture of the metal master;

[0027] Fig. 5 is a cross-sectional view schematically showing the steps of forming a conductive film of the metal master;

[0028] Fig. 6 is a cross-sectional view schematically showing the steps of forming an electrolytic plating layer of the metal master; and

[0029] Fig. 7 is a graph showing the relationship between electroless plating time and thickness of a conductive film.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0030] ~~An embodiment of the present invention will be described in a detailed manner with reference to the drawings.~~ It should be noted that, ~~here, the description will be made taking an example of~~ for ease of explanation, the exemplary embodiment is described within the context of producing a glass master by using a positive-type photoresist and manufacturing a metal master used for manufacture of a DVD-type information recording disc. However, the system and methods are equally applicable to a metal master for use with other types of information recording discs.

[0031] Fig. 1 is a cross-sectional view schematically showing the configuration of a metal master according to the ~~present~~ exemplary embodiment.

[0032] A metal master 10 is constituted by a laminate of a conductive film 12 and an electrolytic plating layer 14, and is characterized in that the conductive film 12 has a thickness t of about 50 nm (that is within the range of 35 nm to 200 nm). Since the other structural features of this metal master are similar to those of ~~the~~ conventional ~~ones~~metal masters, the description will be omitted where appropriate.

[0033] The conductive film 12 is made of a thin substantially circular ~~disc~~ plate of nickel having a thickness of about ~~50nm~~50 nm as described above. The conductive film 12 is provided with fine protrusions 16, which correspond to grooves of an information recording disc, formed in a helical manner. The fine ~~protrusion~~ protrusions 16 ~~has~~ have a height (step height) of about 30 nm. This means that the thickness of the conductive film 12 is greater than the height of the fine ~~protrusion~~ protrusions 16.

[0034] The electrolytic plating layer 14 is also made of a thin substantially circular ~~disc~~ plate of nickel and is formed on the opposite surface of the conductive film 12 from the fine protrusion 16. The electrolytic plating layer 14 has a thickness of about 300 μm.

[0035] ~~The reference numeral 18 in~~ Fig. 1 ~~indicates~~ also shows a glass master 18 used for producing the metal master 10. The glass master 18 is provided with fine depressions 24 on a glass substrate 20, which correspond to grooves of an information recording disc, by using a ~~positive type~~ positive-type photoresist 22. The fine depressions 24 are formed for copying the fine protrusions 16 to the conductive film 12 of the metal master 10 and have a depth of about 30 nm.

[0036] Next, an exemplary embodiment of a method for manufacturing the metal master 10 will be described with reference to Figs. 2 and 3.

Fig. 2 is a flow chart ~~showing the outline of~~outlining manufacturing steps of the metal master 10 and Fig. 3 is a flow chart ~~showing the details of~~detailing steps for forming the conductive film 12.

[0037] ~~In the first step~~First, the glass substrate 20 is smoothly polished and cleaned (S102). After forming a thin film of an adhesive material on the polished surface, the photoresist 22 is applied by the spin coating method to a thickness of about 30 nm (S104). The photoresist 22 is then baked to evaporate a solvent therein and dried (S106). Thereafter, the photoresist 22 is checked for the thickness and defects (S108). ~~Further, the~~The photoresist 22 is ~~developed (S112) after being~~ irradiated with a laser beam in a pattern corresponding to the helical pattern of the grooves (S110) and developed (S112), whereby, as shown in Fig. 4 ~~(S110)~~, an exposed region (region indicated by the two-dot chain line in Fig. 4) is removed to form the fine depressions 24.

[0038] The glass master 18 thus obtained is then provided with the conductive film 12 formed according to the steps as shown in Fig. 3 (S114). ~~Describing more particularly,~~Particularly, as shown in Fig. 3, a colloidal catalyst containing tin and palladium chloride is applied on the glass master 18 by the spin coating method ~~in the first step~~ (S202), and then cleaned with acid to remove tin (S204). As a result, palladium is deposited on the surface of the glass master 18 (S206). When the glass master having palladium deposited on the surface is dipped in (electroless) nickel plating solution (S208), nickel is deposited with the palladium serving as a catalyst (S210). The nickel thus deposited then serves as a catalyst so that further nickel is deposited continuously. By dipping the glass master 18 in the nickel plating solution for about five minutes, the glass master 18 is provided with the conductive film 12 with a thickness of about 50 ~~nm~~ nm, as shown in Fig. 5. The glass master 18 having the conductive film 12 formed thereon is cleaned with water (S212) before being checked for appearance and the like.

[0039] ~~The~~ Returning to Fig. 2, the glass master 18 is then dipped in nickel sulfamate solution and supplied with electricity by using the conductive film 12 as an ~~electrode,~~electrode so that the nickel film is grown to a thickness of about 300 μm to form an electrolytic plating layer ~~14~~ 14, as shown in Fig. 6 (S116). Further, after polishing the opposite surface of the electrolytic plating layer 14 from the conductive film 12 ~~(S118)~~, the conductive film 12 and the electrolytic plating layer 14 are integrally removed from the glass master 18 (S118). If necessary, the shape of the conductive film 12 and the electrolytic plating layer 14 may be adjusted by punching out the inner or outer periphery thereof (S118).

The photoresist is removed with caustic soda, and the conductive film 12 and the electrolytic plating layer 14 are further subjected to ultrasonic cleaning using ultra pure water ~~(S120). The~~(S120), resulting in a complete metal master 10~~is completed in this manner~~.

[0040] By using the metal master 10 thus obtained as a stamper, it is possible to form grooves in an information recording disc substrate (not shown in the drawings) ~~grooves~~ with a concave shape corresponding to the fine depressions 24 of the glass master 18.

[0041] ~~Further,~~Alternatively, if a stamper (not shown in the drawings) is fabricated using the metal master 10 by the same electrolytic plating method as described above, it is possible to form grooves in an information recording disc (not shown in the drawings) ~~grooves~~ with a convex shape corresponding to the fine depressions 24 of the glass master 18.

[0042] ~~Furthermore, if~~ If a mother (not shown in the drawings) is fabricated using the metal master 10 by the same electrolytic plating method as described above and a stamper (not shown in the drawings) is fabricated using the mother by the same electrolytic plating method as described above, it is possible to form grooves in an information recording disc substrate (not shown in the drawings) ~~grooves~~ with a concave shape corresponding to the fine depressions 24 of the glass master 18.

Example

[0043] ~~The height of the fine protrusion of the metal master~~ Metal masters were fabricated according to the ~~embodiment~~ above-described exemplary embodiment. ~~as described above~~ The height of the fine protrusion of the metal master was set to about 30 nm, and ~~metal masters were fabricated~~ the various fabricated metal masters were fabricated having a conductive film with a thickness of 40, 50, 60, 90, 120, 150, and 200 nm, respectively. Using these metal masters, 100 information recording discs having grooves with a depth of about 30 nm were manufactured for each of the metal masters. These information recording discs were then checked for variation in reflectance along the groove thereof. All of the results were favorable.

[0044] It should be noted that the variation in reflectance as mentioned herein was determined by using a Pulstec DDU1000 tester. The information recording disc was irradiated with a laser beam in the state where tracking was off while focusing was on, and reflectance along the groove thereof was measured by measuring an amount of feedback light for the irradiated laser beam so that variation in reflectance was determined. In addition, variation in reflectance in the surface was also determined in a similar manner.

Comparative Example

[0045] For comparing with the above example, metal masters were fabricated having a conductive film with a thickness of 20 and 30 nm, respectively. Using these metal masters, 100 information recording discs having grooves with a depth of about 30 nm were manufactured for each of the metal masters. These information recording discs were checked for variation in reflectance along the groove thereof. In the information recording disc fabricated with the metal master having a conductive film with a thickness of 20 nm, the variation in reflectance was completely over an allowable range. In the information recording disc fabricated with the metal master having a conductive film with a thickness of 30 nm, the variation in reflectance was slightly over the allowable range.

[0046] Although the thickness of the conductive film 12 is set to about 50 nm in the foregoing exemplary embodiment, ~~the present invention is not limited to this, and~~ the thickness of the conductive film 12 may be selected from a range of 35 to 200 nm according to a depth of a pit, a groove, or the like. Specifically, in the case of forming shallow grooves with a depth of about 30 nm, the conductive film may be formed to have a thickness of 35 nm or more, that is larger than the depth of the groove, so that the shapes of the fine protrusions of the metal master corresponding to the grooves can be stabilized since the conductive film constitutes a substantial part of the fine protrusions. On the other hand, considering productivity, durability and so on, it is preferable to set the upper limit of the thickness of the conductive film to about 200 nm.

[0047] In order to stabilize the shapes of the fine protrusions of the metal master more reliably, it is preferable to form the conductive film to have a thickness of 40 nm or more. Further, in order to stabilize the shapes of the fine protrusions of the metal master still more reliably, it is more preferable to form the conductive film to have a thickness of 45 nm or more. In order to form the fine protrusions of the metal master further more accurately, it is still more preferable to form the conductive film to have a thickness of 50 nm or more.

[0048] On the other hand, as shown in Fig. 7, using a typical electroless plating method, the growth of a conductive film tends to rapidly slow down when the thickness of the conductive film exceeds about 150 nm. Therefore, the conductive film is preferably formed to have a thickness of 150 nm or less. In order to further improve ~~the~~ productivity ~~more~~, it is ~~more~~ preferable to form the conductive film to have a thickness of 120 nm or less. If the thickness of the conductive film is 90 nm or less, ~~the~~ productivity can be further improved ~~still more~~. ~~Further, i~~If the thickness of the conductive film is 60 nm or less, the productivity

can be even further improved ~~further more~~, and the productivity can be improved still further ~~more~~ by forming the conductive film to have a thickness of 55 nm or less.

[0049] Thus, the thickness of the conductive film may be selected appropriately from the above-mentioned ~~range~~ ranges according to a depth (or height) of a pit or a groove of an information recording disc to be formed and according to a type of a functional layer, such that variation in reflectance can be reliably limited ~~reliably~~ to such a range as will not pose any problem in practical use and a desirable productivity can be achieved.

[0050] Although the metal master is provided with fine protrusions corresponding to grooves of an information recording disc according to the foregoing exemplary embodiment, the present invention is not limited to this and is applicable also to a metal master that is provided with fine protrusions corresponding to pits of an information recording disc. Further, ~~the present invention is~~various exemplary embodiments are also applicable to a metal master that is provided with fine depressions corresponding to grooves and/or pits of an information recording disc.

[0051] ~~Further, although~~Although the foregoing exemplary embodiment is described ~~taking an example of~~with respect to producing a metal master used for the manufacture of a DVD-type optical disc, the various exemplary embodiments of the ~~present~~ invention ~~is not limited to this and is~~are also applicable to a metal master that is used for the manufacture of other types of information recording discs, such ~~as~~ as, for example, an information recording disc utilizing optical near-field.

[0052] As described above, according to the ~~present~~ various exemplary embodiments of the invention, desirable effects can be obtained ~~such as that~~including the production of a metal master ~~can be produced~~ with ~~higher~~ a more precise shape precision than conventional ~~ones and~~metal masters. Furthermore, the variation in reflectance of an information recording disc with shallow pits and/or grooves and produced with such a metal master can be restricted to an allowable range.

APPENDIX B

METHOD FOR MANUFACTURING METAL MASTER OF INFORMATION RECORDING DISC AND METAL MASTER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The disclosure of Japanese Patent Application No. 2003-049348 filed February 26, 2003 including the specification, drawings, and claims is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of Invention

[0002] The present invention relates to a method for manufacturing a metal master for fabrication of information recording disc substrates and to a metal master.

2. Description of Related Art

[0003] It is crucial in fabrication of an information recording substrate such as an optical disc that the disc substrate has a highly precise shape because if an error in such a disc substrate is large, it will lead to a large variation in reflectance, which will decrease the accuracy of recording/reproducing information.

[0004] A typically known method for manufacturing an information recording disc substrate involves the steps of applying a positive type photoresist, for example, on a glass substrate, irradiating the photoresist with a laser beam, developing and removing the exposed photoresist to produce a glass master with fine depressions and protrusions, copying the fine depressions and protrusions of the glass master to a metal master and then to a stamper, and arranging the stamper in a mold for molding resin to fabricate an information recording disc substrate. The information recording disc substrate manufactured according to this method has an information recording region in which pits and/or grooves are formed by depressions and protrusions copied from the glass master in a reversed fashion. Namely, the depressions are copied as protrusions and the protrusions are copied as depressions. However, it is possible to provide an information recording disc substrate having pits and/or grooves identical to the depressions and protrusions of the glass master (equally copied) if a mother is produced by copying the depressions and protrusions of the metal master in a reverse fashion and then a stamper is produced by copying the protrusions and depressions of the mother in a reverse fashion. It is also possible to provide an information recording disc substrate having pits and/or grooves identical to depressions and protrusions of the glass master (equally copied) if the metal master is used as a stamper.

[0005] The term "metal master" used herein shall be defined as a matrix obtained by removing a conductive film and an electrolytic plating layer formed on a glass master. In other words, herein, any matrix obtained by removing a conductive film and an electrolytic plating layer formed on a glass master shall be called a metal master whether it is used as a stamper or as a matrix for fabricating a stamper or mother.

[0006] The terms "pits" and "grooves" are generally used in relation to CD media (Compact Discs) or DVD media (Digital Video Disk or Digital Versatile Discs) to mean fine depressions formed on an information recording disc substrate for recording information therein. In the present specification, however, the terms "pits" and "grooves" shall be used, for the sake of convenience, to mean fine projections as well as fine depressions formed on such an information recording disc substrate that has a light-transmitting layer formed thereon and receives laser beams from the side of this light-transmitting layer.

[0007] Conventionally, an information recording disc substrate having a highly precise shape has been produced by fabricating a high-precision glass master by smoothly polishing a glass substrate and copying the high-precision glass master to a metal master or the like.

[0008] It should be noted, however, that even a glass master with a highly precise shape produced in this manner may generate a slight error in the shape of the metal master when the shape of the glass master is copied to the metal master. For example, if the formation of a conductive film or an electrolytic plating layer is defective, or if the conductive film and the electrolytic plating layer are peeled off from each other, the error in the shape of the metal master will be increased to an extent such that a metal master thus produced is not usable. For coping with this problem, various technologies have been developed to form a conductive film and an electrolytic plating layer such that the error in the metal master can be minimized (see, for example, Japanese Patent Publication No. 2663912). As a result, the error in a metal master now rarely poses a problem in practical use.

[0009] Nevertheless, when comparing various information recording discs with equivalent shape errors, those with shallower pits and/or grooves tend to exhibit larger variation in reflectance.

[0010] In recent years, there has been an increase in the production of information recording discs with shallower pits and/or grooves than conventional information recording discs to cope with the increase in the capacity of information recording discs or the diversification of recording methods. For example, in DVD-R media (Digital Versatile

Discs-Recordable), the depth of grooves is approximately 150 nm, in MD media (Mini Discs), the depth of grooves is approximately 100 nm, and in DVD-RW media (Digital Versatile Discs-Rewritable), the depth of grooves is approximately 30nm.

[0011] Also, there has been proposed a large capacity information recording disc in which an information recording disc substrate is provided with a light-transmitting layer with a thickness as small as about 0.1 mm. It is believed that, even in such a large-capacity information recording disc, the depth of grooves is desirably about 30 nm.

[0012] As the depth of pits and/or grooves of information recording discs becomes smaller, there has arisen a new problem. The small shape error in metal masters, that was not problematic in conventional technologies, can cause harmful effects that result in variation in reflectance of information recording discs with large capacity (i.e., smaller pits and/or grooves) and hence a decrease the information recording/reproducing accuracy of the large capacity recording discs.

SUMMARY OF THE INVENTION

[0013] In view of the foregoing problems, various exemplary embodiments of this invention provide a metal master with a more precise shape than conventional metal masters. Furthermore, various exemplary embodiments of the invention provide a method for manufacturing such a metal master.

[0014] Various exemplary embodiments of the invention achieve the foregoing object by forming a conductive film of a metal master to have a thickness greater than the thickness of conventional metal masters.

[0015] Although it is not clearly known why the shape precision of a metal master can be improved by forming a conductive film of the metal master to have a thickness greater than conventional ones, the reason can be largely assumed as follows.

[0016] In the first step of forming a conductive film, a catalyst is applied, but it is difficult to make the thickness of the catalyst layer uniform. Thus, if a conductive film is thin, it is believed that any nonuniformity in the thickness of the catalyst layer will cause a corresponding nonuniformity in thickness of the conductive film. The thickness of the conductive film affects the electrolytic plating layer, thereby contributing to a small error in the shape of the metal master. To cope with this problem, a conductive film can be formed thick enough to absorb the nonuniformity in thickness of the catalyst layer, and hence the nonuniformity in thickness of the conductive layer can be minimized. As a result, a metal

master with a highly precise shape can be formed by forming the electrolytic plating layer on the conductive film that has been formed with minimal nonuniformity in thickness.

[0017] Further, when a conductive film is thin enough for the depth of pits and/or grooves, it is believed that the effect exerted by such thin conductive film to the precision of the shape of the pits and grooves is small because fine projections of a metal master corresponding to the pits and/or grooves are mainly constituted by an electrolytic plating layer. However, as the depth of pits and/or grooves becomes smaller, the percentage occupied by the conductive film in the constitution of the fine projections of the metal master is increased so that the fine projections are constituted by the conductive film and electrolytic plating layer serving like a composite material, which contributes to an error in the shape of the fine projections of the metal master. To cope with this, it is believed that the error in the shape of the fine projections can be decreased by forming the conductive film thick enough that the projections of the metal master are mainly constituted by the conductive film.

[0018] In other words, while it has been conventionally believed that an electrolytic plating layer mainly constitutes a metal master and a conductive film is only an electrode for forming the electrolytic plating layer, various exemplary embodiments of the invention improve the precision of the shape of a metal master by using a conductive film as a more substantial constituent of the metal master. Thus, various exemplary embodiments of this invention are based on a view point and conception contrary to conventional practice.

[0019] Accordingly, various exemplary embodiments of the invention provide a method for manufacturing a metal master including forming a conductive film by an electroless plating method on a glass master having fine depressions and protrusions for forming an information recording region of an information recording disc; forming an electrolytic plating layer by an electrolytic plating method on the conductive film; and removing the conductive film and the electrolytic plating layer from the glass master to provide a metal master, wherein the conductive film is formed to have a thickness of 35 nm to 200 nm.

[0020] Alternatively, various exemplary embodiments of the invention provide a method for manufacturing a metal master including forming a conductive film by an electroless plating method on a glass master having fine depressions and protrusions for forming an information recording region of an information recording disc; forming an electrolytic plating layer by an electrolytic plating method on the conductive film; and removing the conductive film and the electrolytic plating layer from the glass master to

provide a metal master, wherein the conductive film is formed to have a thickness greater than a step height of the fine depressions and protrusions of the glass master.

[0021] Various exemplary embodiments of the invention provide a metal master including a conductive film having copied fine depressions and protrusions for forming an information recording region of an information recording disc, and an electrolytic plating layer formed on the conductive film, wherein the thickness of the conductive film is greater than a step height of the fine depressions and protrusions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Various exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings, wherein:

[0023] Fig. 1 is a cross-sectional view schematically showing the configuration of a metal master according an embodiment of the present invention;

[0024] Fig. 2 is a flow chart showing the outline of a method for manufacturing the metal master;

[0025] Fig. 3 is a flow chart showing the details of the steps for forming a conductive film of the metal master;

[0026] Fig. 4 is a cross-sectional view schematically showing the steps of forming a glass master used for the manufacture of the metal master;

[0027] Fig. 5 is a cross-sectional view schematically showing the steps of forming a conductive film of the metal master;

[0028] Fig. 6 is a cross-sectional view schematically showing the steps of forming an electrolytic plating layer of the metal master; and

[0029] Fig. 7 is a graph showing the relationship between electroless plating time and thickness of a conductive film.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0030] It should be noted that, for ease of explanation, the exemplary embodiment is described within the context of producing a glass master by using a positive-type photoresist and manufacturing a metal master used for manufacture of a DVD-type information recording disc. However, the system and methods are equally applicable to a metal master for use with other types of information recording discs.

[0031] Fig. 1 is a cross-sectional view schematically showing the configuration of a metal master according to the exemplary embodiment.

[0032] A metal master 10 is constituted by a laminate of a conductive film 12 and an electrolytic plating layer 14, and is characterized in that the conductive film 12 has a thickness t of about 50 nm (that is within the range of 35 nm to 200 nm). Since the other structural features of this metal master are similar to those of conventional metal masters, the description will be omitted where appropriate.

[0033] The conductive film 12 is made of a thin substantially circular plate of nickel having a thickness of about 50 nm as described above. The conductive film 12 is provided with fine protrusions 16, which correspond to grooves of an information recording disc, formed in a helical manner. The fine protrusions 16 have a height (step height) of about 30 nm. This means that the thickness of the conductive film 12 is greater than the height of the fine protrusions 16.

[0034] The electrolytic plating layer 14 is also made of a thin substantially circular plate of nickel and is formed on the opposite surface of the conductive film 12 from the fine protrusion 16. The electrolytic plating layer 14 has a thickness of about 300 μm.

[0035] Fig. 1 also shows a glass master 18 used for producing the metal master 10. The glass master 18 is provided with fine depressions 24 on a glass substrate 20, which correspond to grooves of an information recording disc, by using a positive-type photoresist 22. The fine depressions 24 are formed for copying the fine protrusions 16 to the conductive film 12 of the metal master 10 and have a depth of about 30 nm.

[0036] Next, an exemplary embodiment of a method for manufacturing the metal master 10 will be described with reference to Figs. 2 and 3. Fig. 2 is a flow chart outlining manufacturing steps of the metal master 10 and Fig. 3 is a flow chartdetailing steps for forming the conductive film 12.

[0037] First, the glass substrate 20 is smoothly polished and cleaned (S102). After forming a thin film of an adhesive material on the polished surface, the photoresist 22 is applied by the spin coating method to a thickness of about 30 nm (S104). The photoresist 22 is then baked to evaporate a solvent therein and dried (S106). Thereafter, the photoresist 22 is checked for the thickness and defects (S108). The photoresist 22 is irradiated with a laser beam in a pattern corresponding to the helical pattern of the grooves (S110) and developed (S112), whereby, as shown in Fig. 4, an exposed region (region indicated by the two-dot chain line in Fig. 4) is removed to form the fine depressions 24.

[0038] The glass master 18 thus obtained is then provided with the conductive film 12 formed according to the steps as shown in Fig. 3 (S114). Particularly, as shown in Fig. 3,

a colloidal catalyst containing tin and palladium chloride is applied on the glass master 18 by the spin coating method (S202), and then cleaned with acid to remove tin (S204). As a result, palladium is deposited on the surface of the glass master 18 (S206). When the glass master having palladium deposited on the surface is dipped in (electroless) nickel plating solution (S208), nickel is deposited with the palladium serving as a catalyst (S210). The nickel thus deposited then serves as a catalyst so that further nickel is deposited continuously. By dipping the glass master 18 in the nickel plating solution for about five minutes, the glass master 18 is provided with the conductive film 12 with a thickness of about 50 nm, as shown in Fig. 5. The glass master 18 having the conductive film 12 formed thereon is cleaned with water (S212) before being checked for appearance and the like.

[0039] Returning to Fig. 2, the glass master 18 is then dipped in nickel sulfamate solution and supplied with electricity by using the conductive film 12 as an electrode so that the nickel film is grown to a thickness of about 300 μm to form an electrolytic plating layer 14, as shown in Fig. 6 (S116). Further, after polishing the opposite surface of the electrolytic plating layer 14 from the conductive film 12, the conductive film 12 and the electrolytic plating layer 14 are integrally removed from the glass master 18 (S118). If necessary, the shape of the conductive film 12 and the electrolytic plating layer 14 may be adjusted by punching out the inner or outer periphery thereof (S118). The photoresist is removed with caustic soda, and the conductive film 12 and the electrolytic plating layer 14 are further subjected to ultrasonic cleaning using ultra pure water (S120), resulting in a complete metal master 10.

[0040] By using the metal master 10 thus obtained as a stamper, it is possible to form grooves in an information recording disc substrate (not shown in the drawings) with a concave shape corresponding to the fine depressions 24 of the glass master 18.

[0041] Alternatively, if a stamper (not shown in the drawings) is fabricated using the metal master 10 by the same electrolytic plating method as described above, it is possible to form grooves in an information recording disc (not shown in the drawings) with a convex shape corresponding to the fine depressions 24 of the glass master 18.

[0042] If a mother (not shown in the drawings) is fabricated using the metal master 10 by the same electrolytic plating method as described above and a stamper (not shown in the drawings) is fabricated using the mother by the same electrolytic plating method as described above, it is possible to form grooves in an information recording disc substrate (not

shown in the drawings) with a concave shape corresponding to the fine depressions 24 of the glass master 18.

Example

[0043] Metal masters were fabricated according to the above-described exemplary embodiment. The height of the fine protrusion of the metal master was set to about 30 nm, and the various fabricated metal masters were fabricated having a conductive film with a thickness of 40, 50, 60, 90, 120, 150, and 200 nm, respectively. Using these metal masters, 100 information recording discs having grooves with a depth of about 30 nm were manufactured for each of the metal masters. These information recording discs were then checked for variation in reflectance along the groove thereof. All of the results were favorable.

[0044] It should be noted that the variation in reflectance as mentioned herein was determined by using a Pulstec DDU1000 tester. The information recording disc was irradiated with a laser beam in the state where tracking was off while focusing was on, and reflectance along the groove thereof was measured by measuring an amount of feedback light for the irradiated laser beam so that variation in reflectance was determined. In addition, variation in reflectance in the surface was also determined in a similar manner.

Comparative Example

[0045] For comparing with the above example, metal masters were fabricated having a conductive film with a thickness of 20 and 30 nm, respectively. Using these metal masters, 100 information recording discs having grooves with a depth of about 30 nm were manufactured for each of the metal masters. These information recording discs were checked for variation in reflectance along the groove thereof. In the information recording disc fabricated with the metal master having a conductive film with a thickness of 20 nm, the variation in reflectance was completely over an allowable range. In the information recording disc fabricated with the metal master having a conductive film with a thickness of 30 nm, the variation in reflectance was slightly over the allowable range.

[0046] Although the thickness of the conductive film 12 is set to about 50 nm in the foregoing exemplary embodiment, the thickness of the conductive film 12 may be selected from a range of 35 to 200 nm according to a depth of a pit, a groove, or the like. Specifically, in the case of forming shallow grooves with a depth of about 30 nm, the conductive film may be formed to have a thickness of 35 nm or more, that is larger than the depth of the groove, so that the shapes of the fine protrusions of the metal master corresponding to the grooves can be

stabilized since the conductive film constitutes a substantial part of the fine protrusions. On the other hand, considering productivity, durability and so on, it is preferable to set the upper limit of the thickness of the conductive film to about 200 nm.

[0047] In order to stabilize the shapes of the fine protrusions of the metal master more reliably, it is preferable to form the conductive film to have a thickness of 40 nm or more. Further, in order to stabilize the shapes of the fine protrusions of the metal master still more reliably, it is more preferable to form the conductive film to have a thickness of 45 nm or more. In order to form the fine protrusions of the metal master further more accurately, it is still more preferable to form the conductive film to have a thickness of 50 nm or more.

[0048] On the other hand, as shown in Fig. 7, using a typical electroless plating method, the growth of a conductive film tends to rapidly slow down when the thickness of the conductive film exceeds about 150 nm. Therefore, the conductive film is preferably formed to have a thickness of 150 nm or less. In order to further improve productivity, it is preferable to form the conductive film to have a thickness of 120 nm or less. If the thickness of the conductive film is 90 nm or less, productivity can be further improved. If the thickness of the conductive film is 60 nm or less, the productivity can be even further improved, and the productivity can be improved still further by forming the conductive film to have a thickness of 55 nm or less.

[0049] Thus, the thickness of the conductive film may be selected appropriately from the above-mentioned ranges according to a depth (or height) of a pit or a groove of an information recording disc to be formed and according to a type of a functional layer, such that variation in reflectance can be reliably limited to such a range as will not pose any problem in practical use and a desirable productivity can be achieved.

[0050] Although the metal master is provided with fine protrusions corresponding to grooves of an information recording disc according to the foregoing exemplary embodiment, the present invention is not limited to this and is applicable also to a metal master that is provided with fine protrusions corresponding to pits of an information recording disc. Further, various exemplary embodiments are also applicable to a metal master that is provided with fine depressions corresponding to grooves and/or pits of an information recording disc.

[0051] Although the foregoing exemplary embodiment is described with respect to producing a metal master used for the manufacture of a DVD-type optical disc, the various exemplary embodiments of the invention are also applicable to a metal master that is used for

the manufacture of other types of information recording discs, such as, for example, an information recording disc utilizing optical near-field.

[0052] As described above, according to the various exemplary embodiments of the invention, desirable effects can be obtained including the production of a metal master with a more precise shape precision than conventional metal masters. Furthermore, the variation in reflectance of an information recording disc with shallow pits and/or grooves and produced with such a metal master can be restricted to an allowable range.

ABSTRACT OF THE DISCLOSURE

A metal master having a more precise shape than conventional metal masters and a method for manufacturing the metal master. The metal master has a conductive film having a thickness within a range of 35 nm to 200 nm.